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TEST OF MAP-READ MAGNETIC DECLINATION ACCURACY.(U)
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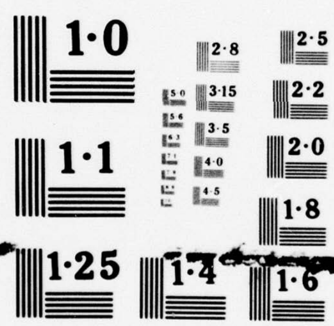
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Test of map-read magnetic declination accuracy

Glenn W. Schmeidel

MAY 1978

U.S. ARMY CORPS OF ENGINEERS
ENGINEER TOPOGRAPHIC LABORATORIES
FORT BELVOIR, VIRGINIA 22060

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This report covers a test of how accurately a map-referenced magnetic declination represents the actual magnetic declination found by measuring true north and magnetic north at various points selected at random within the mapped area. The undeveloped area in Quantico, Virginia was investigated and found to have individual variations as great as 23 mils, with a 1-sigma standard deviation of 8 mils from the map-read value.

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CONTENTS

ILLUSTRATIONS

TABLE

PREFACE

Authority for the test and evaluation covered by this report came from Project 1S763712D673, "Forward Observer Vehicle (FOV) Kit," Task 12, Work Unit 0001, from Headquarters, U.S. Army Material Command, 9 January 1975, subject: "Draft Proposed Letter of Agreement (LOA) for a Forward Observer Vehicle (FOV) Kit."

The work on this project was accomplished by Glenn W. Schmeidel, Donald P. Dere, and G.W. Bunch under the supervision of Milton Goldin, Chief, Electronics Surveying Branch, and the direction of Carl R. Friberg, Jr., Chief, Surveying and Engineering Division, U.S. Army Engineer Topographic Laboratories (USAETL).

TEST OF MAP-READ MAGNETIC DECLINATION ACCURACY

INTRODUCTION

SCOPE

This report presents a comparison of magnetic and true azimuths measured at 25 test sites evenly spaced over an approximately 10 X 14 km area in the vicinity of Quantico, Virginia. The 25 test sites were selected in undeveloped areas so that any magnetic influences caused by man-made structures would not bias the data. In order to determine the effect of man-made structures on the local magnetic field, additional measurements were made at 4 locations in the immediate proximity of buildings and other structures. Measurements were made at only 2 locations in each of the 25 remote test sites, but mulitple measurements were required at each of the 4 locations near man-made structures because the structures had such a pronounced effect on the measurements.

BACKGROUND

The need for an accurate azimuth reference for vehicular use has been obvious for many years. North-seeking gyrocompasses for vehicular use have been developed recently in Europe but they are bulky, slow, expensive, and require a second, direction gyroscope for in-motion use. A compensated magnetic flux-gate compass, the POS-406, was also recently developed. This instrument has an accuracy in the order of 3 mils 1-sigma.[1] Before the POS-406 can be seriously considered as a vehicular azimuth reference for high accuracy applications (3-5 mils) for vehicle heading and target bearing it is necessary to know how well measured magnetic readings at various points within one map sheet agree with the printed magnetic to true correction on the map sheet. Multiple test sites were selected in undeveloped areas to show a pattern of small area changes in earth magnetic north. Within each test site 2 points, A and B approximately 10 meters apart, were read to provide an indication of the microscopic changes in the direction of the earth's magnetic field. At the four locations having buildings in near-proximity, readings were taken at a series of points about 10 meters apart. These points formed an 80-meter cross centered on former POS-406 test points. These data were collected for future use in studying changes in magnetic field in developed areas (near man-made structures). A prerequisite for consideration of magnetic azimuth in developed areas is its suitability in undeveloped areas. The magnetic azimuth at any point on the earth has diurnal and annual changes which are predictable. The changes for this area are taken as those measured at the magnetic observatory, Fredericksburg, Virginia. The actual change values are plotted and distributed as *magnetograms.* The magnetogram presents the actual azimuth changes at the observatory as a base (constant) value plus the instantaneous variational value with time of day as one ordinate of the plot.

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[1] Glenn W. Schmeidel, *Platform Orientation System Test Program,* U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060, ETL - 0100, November 1976, NTIS: AD-A040 599.

PROGRAM OBJECTIVE

The primary objective was to determine the magnitude and distribution of the differences (error) between magnetic-north corrected and true-north azimuth over the area covered on a single map-sheet. A secondary objective was to determine the magnitude of the effect caused by buildings and other man-made structures with magnetic field.

INVESTIGATION

TEST FACILITIES

The test sites related to the primary objective were located at undeveloped points having easy access (see test plan, Appendix A). The map of the Quantico Military Reservation[2] was divided into 25 parts and two points remote from buildings were selected in each. The first point selected was identified as the A point, the second as B. All B points were within 10 meters of its associated A. The secondary-objective test sites were located at stations used in the ETL, March, 1977 test[3] of the POS–406. These locations are shown in figures 4 through 7 and described in Appendix C.

Test support equipment consisted of Surveying Instrument Azimuth, Gyro, Lightweight (SIAGL), M-2 aiming circle, T-2 Theodolite, and an ETL vehicle. ETL personnel calibrated the M-2 aiming circle at Pier 5C of the U.S. Geological Survey, magnetic center, Fredericksburg, Virginia. The M-2 aiming circle and the SIAGL were used to determine the absolute difference between magnetic-north and true-north. True-north was referenced from the SIAGL to the M-2 by sighting the objective lens of the M-2 through the SIAGL optics while the SIAGL objective lens was sighted through the M-2 optics (see figure 1). The M-2 was read 10 times at magnetic north, with the scope turned slightly away from magnetic-north before each of the 10 readings were made. The time was recorded for each of the readings. The M-2 was then moved to point B, a minimum of 10 meters from its previous location and 10 meters from the SIAGL and the 10-reading collection sequence was repeated.

At the locations used in the POS–406 test (secondary objective of this test) the data collection procedure was different. The T-2 theodolite was set at the center of each of the four test sites. Four points, 10 meters or less apart, on each of the cardinal headings were selected for measurement giving a total of 16 points at each location.

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[2]Defense Mapping Agency Topographic Center Marine Corps Base, Quantico, Virginia Map, Special Edition No 1, DMATC, Series V8345.

[3] Glenn W. Schmeidel, "Test of the POS-406," (unpublished report) U.S. Army Engineer Topographic Laboratories, Fort Belvoir, Virginia 22060.

STEPS

1. Determine north on the SIAGL.
2. Mutually sight the objective lens of the SIAGL with the M_2.
3. Adjust the M_2 horizontal circle to the correct reading.

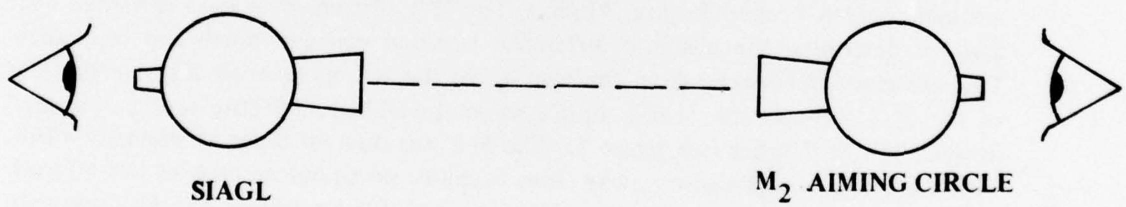


Figure 1. TRANSFERRING REFERENCE AZIMUTH

At each point at which a magnetic azimuth reading was taken the diurnal and annual changes in declination had to be removed so an evaluation of the earths magnetic field could be made. Prior discussions with personnel at the Fredericksburg Magnetic Center had shown that their magnetograms would be the only method of removing these variations, even though it was measured miles from the points of interest. For each location (average of points A and B) the difference between magnetic azimuth and true azimuth is the apparent declination. The magnetogram (figure 2) presents total declination measured at the Fredericksburg Magnetic Center as a function of time of day. The magnetogram shows two declination curves marked D with two horizontal and two vertical intensity curves marked H and Z, respectively. The H and Z curves were not used in this report other than for scale factor determination. The lower D straight-line curve represents the average (or base) declination at Fredericksburg, Virginia, while the top D curve represents the instantaneous (or variable) declination. The base declination at Fredericksburg, Virginia, during the test period was measured at 7^0 53 .7′(140.3 mils). This represents the distance D_{base} minus H_{base} which measures 100.1 millimeters (mm), thereby, giving a scale factor of 1.4 mils per mm.

DECLINATION COMPUTATION

The variable declination was determined as the distance between the two D curves utilizing the above scale factor. This variable declination was determined for each set of 10 compass readings and averaged over that time period. This variation was then added to the updated map value of 140.3. This sum was then subtracted from the measured average of points A and B for each location (see Table 1).

TEST RESULTS

The test results of the Quantico undeveloped area (see Table 1 and figure 3) show differences between the map value and the measured declinations of up to 23 mils for individual readings and approximately 8 mils for a one-sigma standard deviation. The magnetic declinations measured around the ETL, POS-406 test stations (see figures 4 through 7) show variations from 46.1 mils (figure 5) to 259.3 mils (figure 4) over the approximate 80 meter cross lengths.

DISCUSSION

DISCUSSION OF RESULTS

The position A measurements, at each division (Table 1), have approximately the same average and standard deviation values that appear for the position B measurement at the individual locations. The A reading differs from the B reading by as much as 8 mils (figure 3). The reason for those differences is not due to differences in the variable declination found on the magnetogram, nor is it due to the influence of the SIAGL in the area. The SIAGL was removed from the area entirely and the

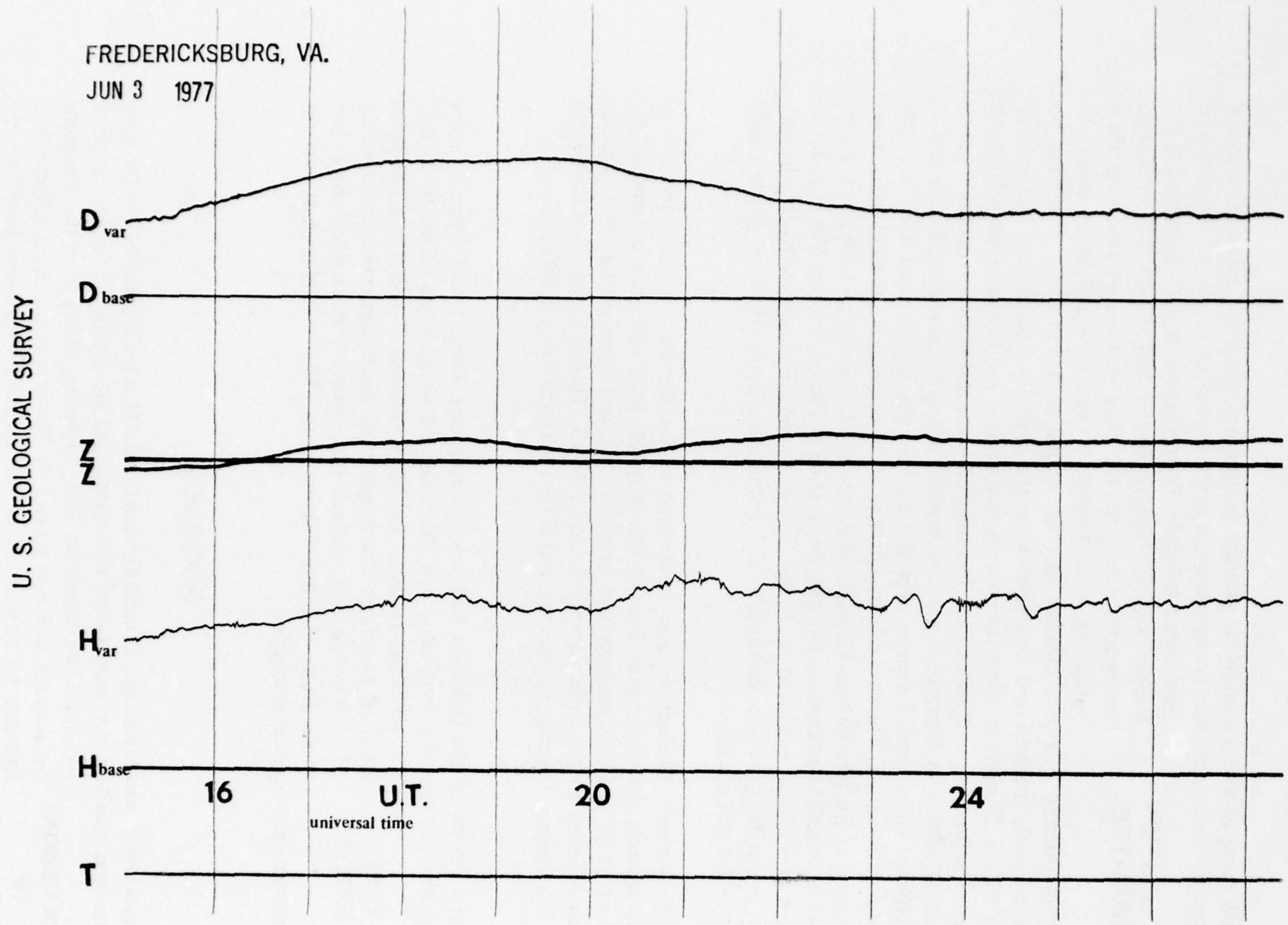


Figure 2. A TYPICAL MAGNETOGRAM

TABLE 1. MEASURED VERSUS MAP-READ MAGNETIC DECLINATION QUANTICO, VIRGINIA

STA NO	DATE (June 1977)	TIME START	TIME END	POSITION A (Units in Mils)	POSITION B (Units in Mils)	A, B AVE	Magnetogram Correction	ERROR: MEAS.(-) Map
1	7	0858	0939	135.6	139.4	137.5	0.8	-3.6
2	7	1018	1048	153.9	157.2	155.5	1.4	13.8
3	7	1143	1213	139.6	145.2	142.4	2.9	-0.8
4	8	0932	0959	144.7	148.9	146.8	1.6	4.9
5	8	1042	1108	146.4	151.8	149.1	2.3	6.5
6	8	1203	1244	146.5	150.8	148.6	3.5	4.8
7	8	1340	1406	140.7	148.7	144.7	4.1	0.3
8	10	1150	1213	133.4	132.1	132.7	4.0	-11.6
9	7	1301	1329	128.7	125.3	127.0	3.9	-17.2
10	13	0913	0937	146.2	141.2	143.7	1.0	2.4
11	29	1029	1053	148.7	141.8	145.2	0.6	4.3
12	10	1029	1052	125.5	133.3	129.4	3.6	-14.5
13	10	1249	1310	146.2	151.4	148.8	4.2	4.3
14	16	1301	1334	147.9	146.1	147.0	3.2	3.5
15	29	1141	1206	147.6	144.9	146.2	2.5	3.4
16	15	1027	1049	146.7	139.4	143.0	3.9	-1.2
17	16	1042	1104	140.5	144.1	142.3	1.5	0.5
18	16	0910	0944	164.2	163.4	163.8	0.3	23.2
19	13	1200	1226	141.0	139.0	140.0	3.1	-3.4
20	13	1039	1100	145.1	142.8	143.9	2.2	1.4
21	3	1023	1060	142.0	145.5	143.7	1.9	1.5
22	13	1312	1336	143.8	139.4	141.6	3.7	-2.4
23	27	1330	1411	150.0	146.6	148.3	4.8	3.2
24	15	1304	1334	145.2	143.5	144.3	4.7	-0.7
25	15	1200	1224	140.7	136.8	138.7	4.4	-6.0
AVERAGE VALUE, = $\bar{x}$				143.6	143.9	143.8	2.8	0.7
STD, DEV., 1-Sigma, = σ				7.8	8.0	7.5	1.3	8.0

CALCULATION EXAMPLE (station 1):

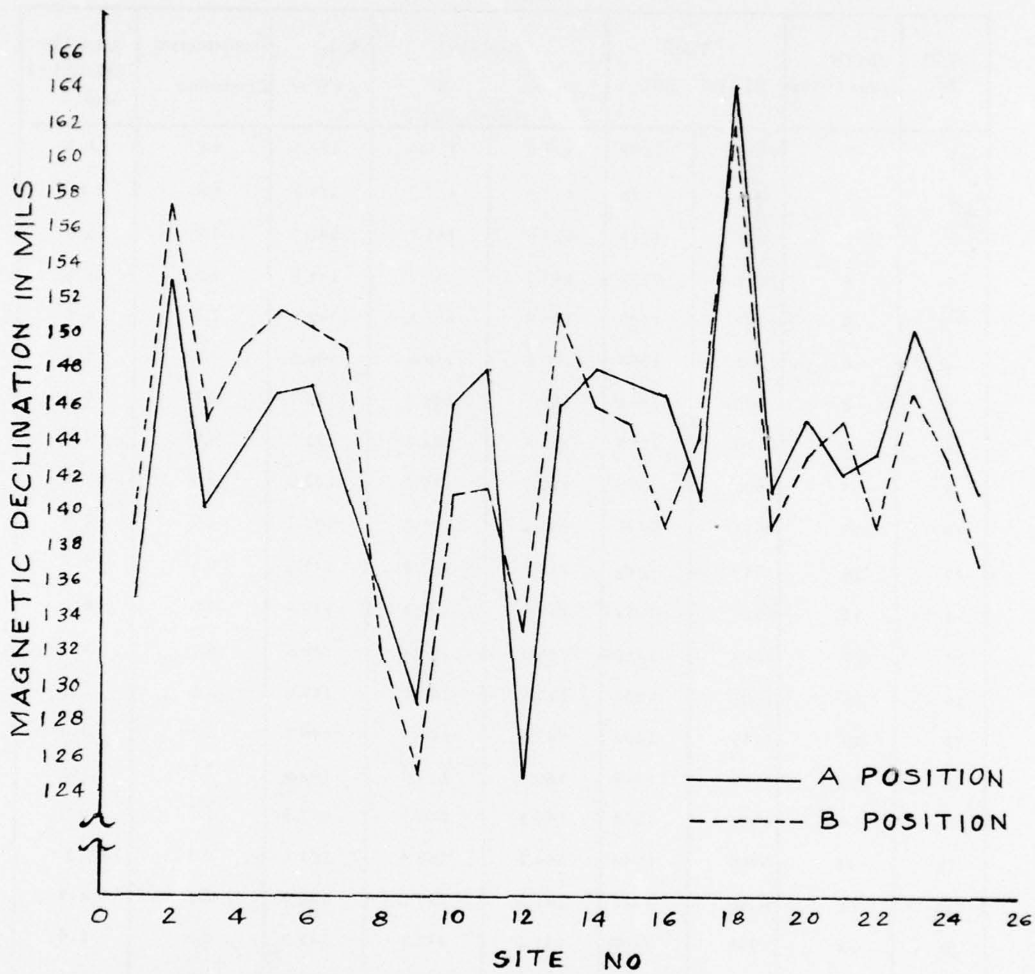
A, B AVE = — — — — — — — — 137.5 mils

MAP VALUE = 140.3 mils

MAG. CORR. = + 0.8

$\quad$ 141.1

ERROR $\quad$ -3.6 mils



A Position X = 143.6, Std Dev = 7.8 mils

B Position X = 143.9, Std Dev = 8.0 mils

A + B Average = 143.8, Std Dev = 7.5 mils

Map-read updated value = 140.3 mils

Figure 3. MAGNETIC DECLINATION VARIATION - QUANTICO, VIRGINIA AREA (2 points per site)

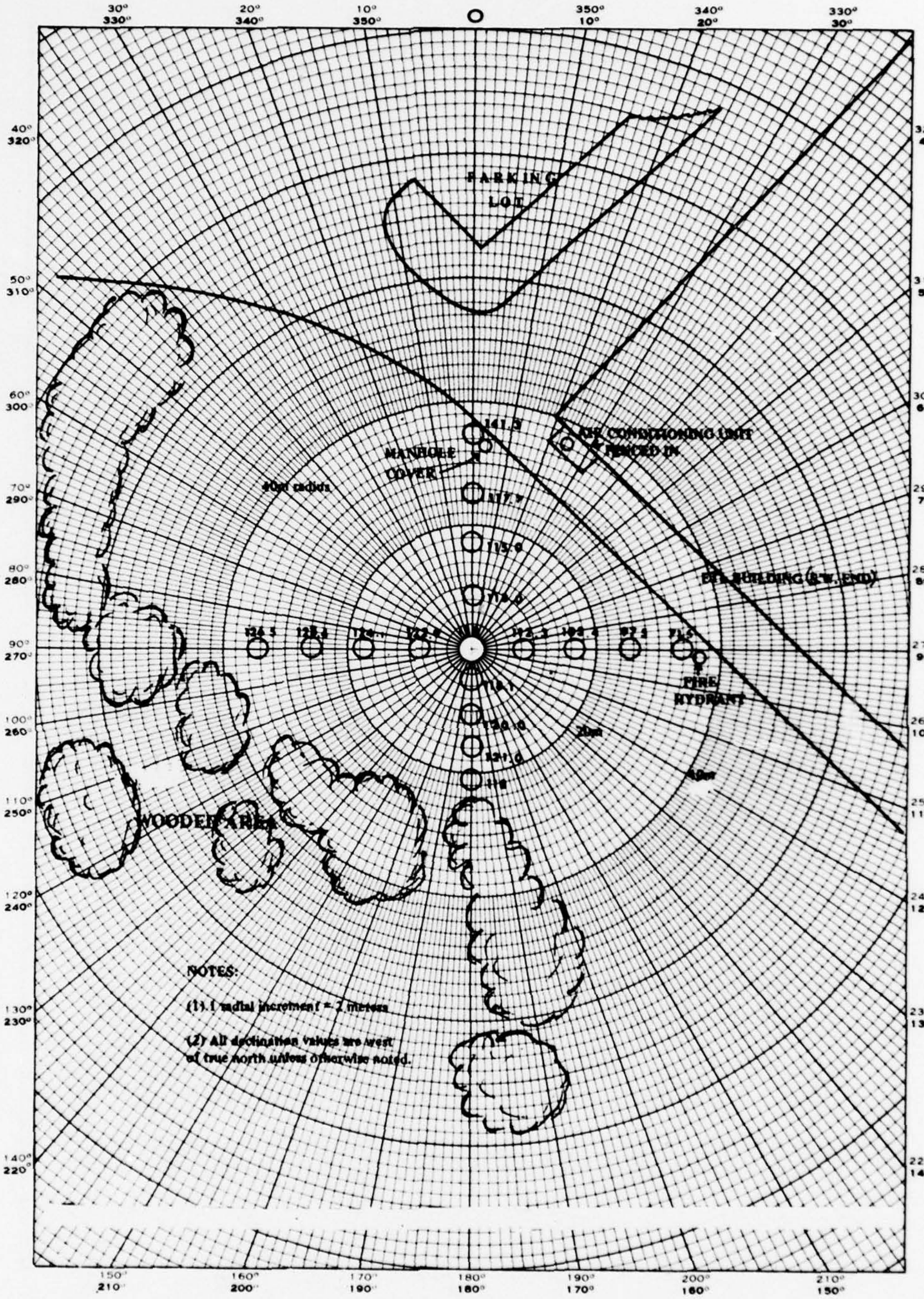


Figure 4. MAGNETIC DECLINATION DISTRIBUTION - ETL BACKYARD AREA (MILS)

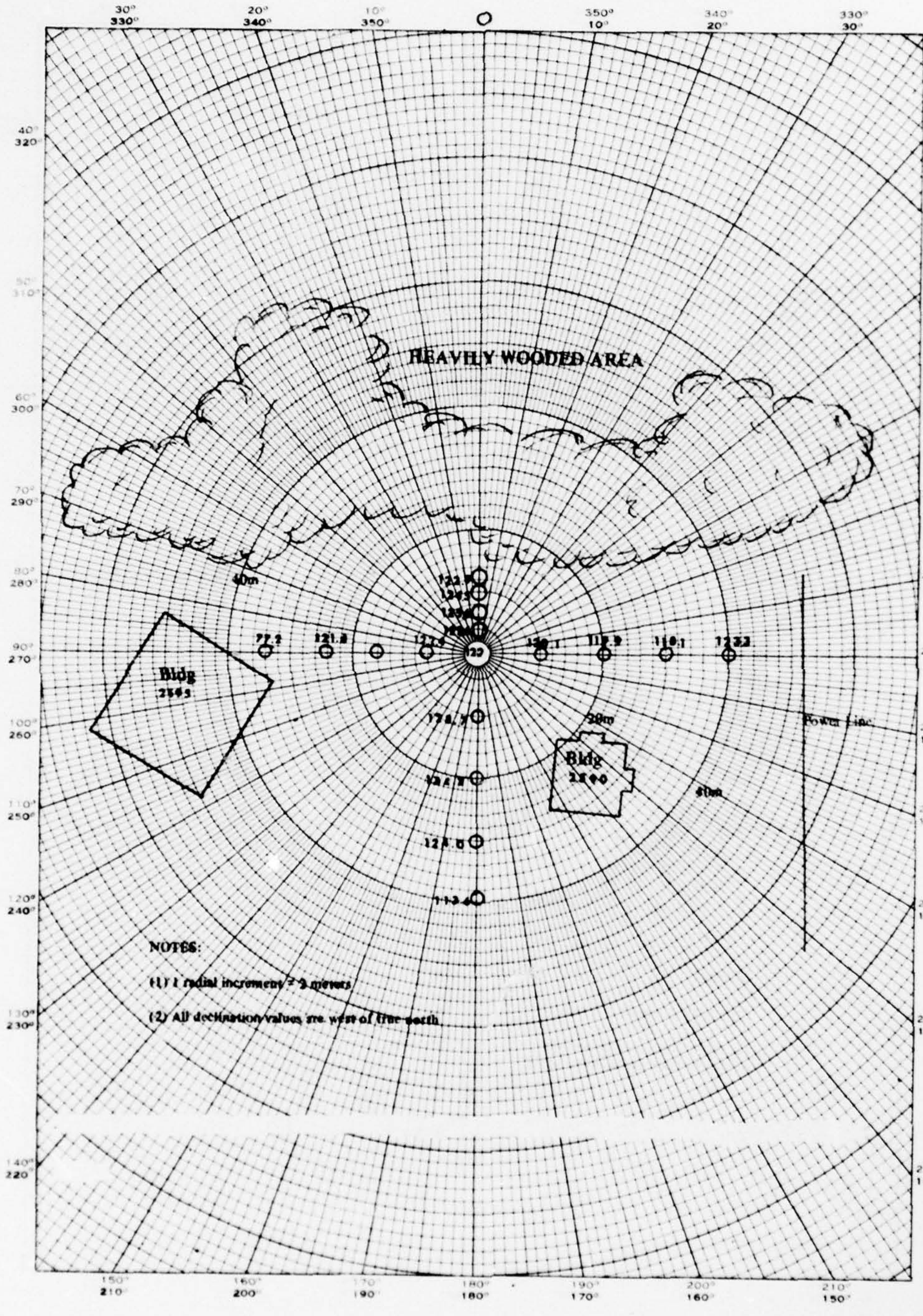


Figure 5. MAGNETIC DECLINATION DISTRIBUTION - SOUTH LEAF ROAD AREA (MILS)

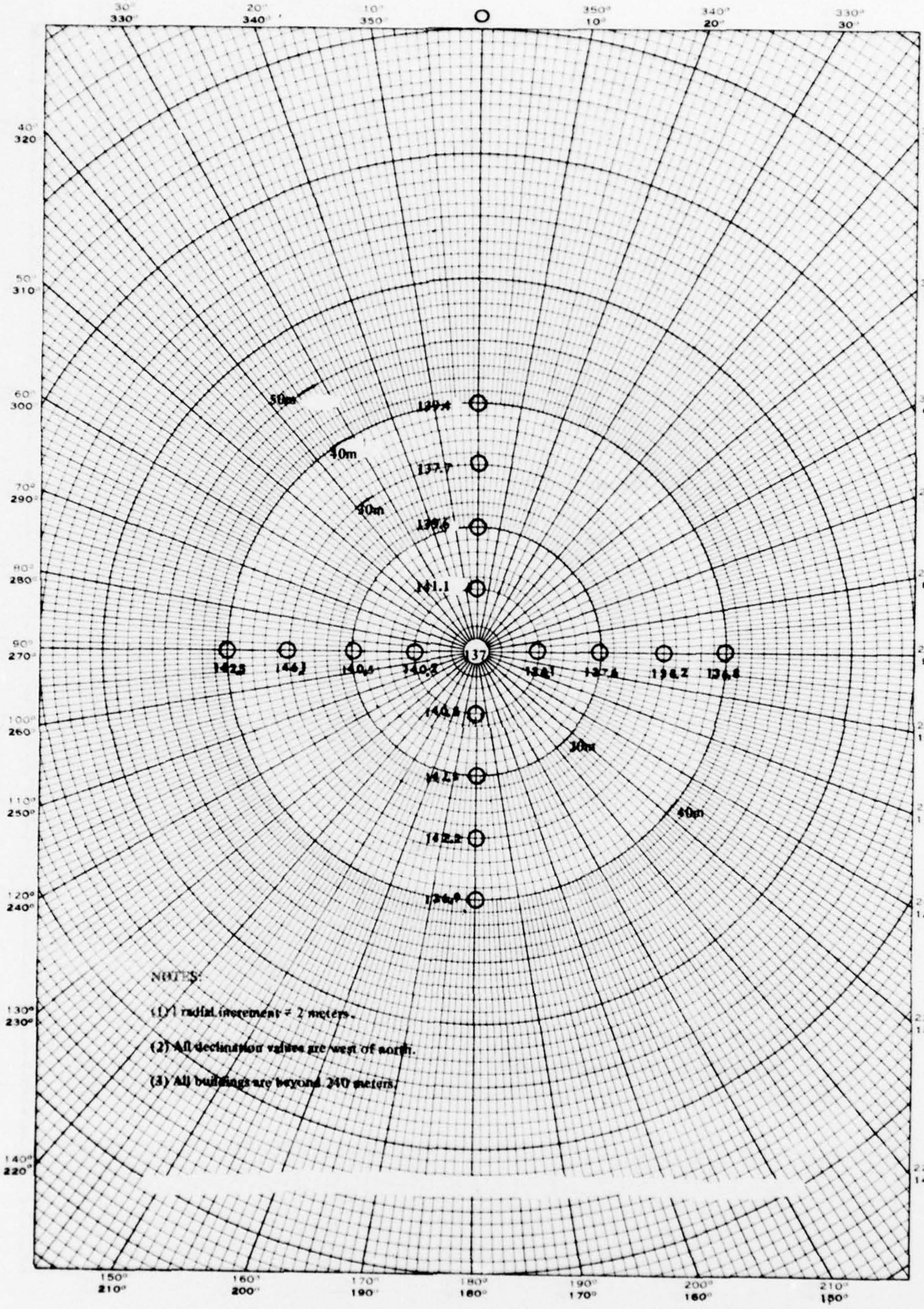


Figure 6. MAGNETIC DECLINATION DISTRIBUTION - EPG AREA (MILS)

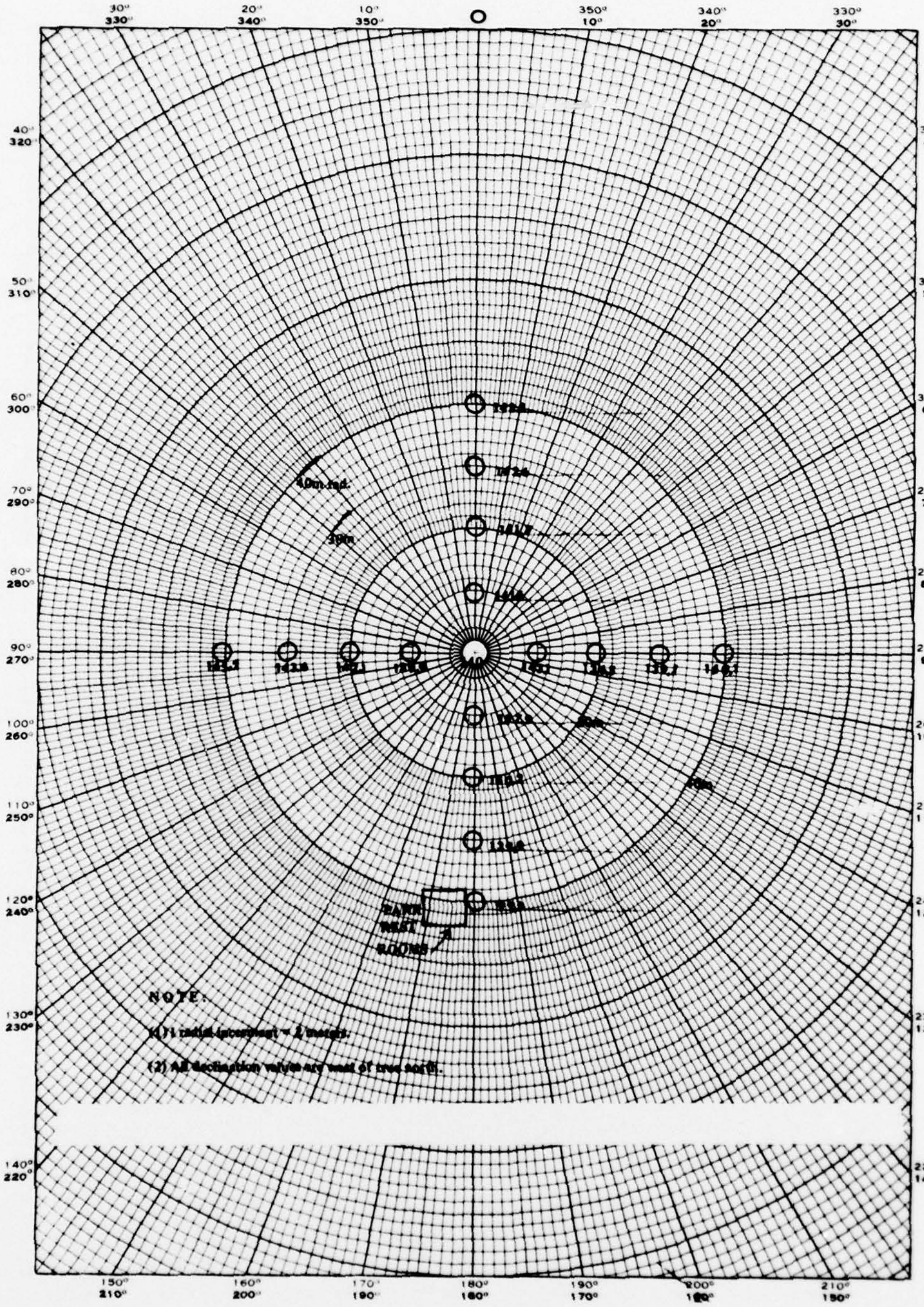


Figure 7. MAGNETIC DECLINATION DISTRIBUTION - FORT HUNT AREA (MILS)

difference remained. Since no specific error source could be identified it is considered to be due to anomaly differences existing in the surface of the earth at various locations.

The difference between the map-read declination and the measured value varies from 17 mils below to 23 mils above the corrected 140.3-mil map-read value. The map-read value was updated from the 1975 value of 137 mils using the 1.30 mils per year for 2½ years. The average measured declination value is within 3.5 mils of the map-read value and the standard deviation from the map-read value is approximately 8 mils one-sigma.

Table 1 shows the average of the last column error minus variable declination to be 0.7 mils. This is misleading since the low average will not improve the individual readings for target location. The low average, however, does indicate that a magnetic compass could be used advantageously in an en route navigation system.

CONCLUSION

The difference between the measured and map-read magnetic declinations (23 mils peak and 8 mils, 1-sigma) is:

1. Too large for the absolute target location functions which include vehicle and vehicle to target bearings of 3-5 mils each.

2. Within an acceptable value for en route navigation.

The changes in declination in developed areas where buildings and other man-placed anomalies are in close proximity are much too unpredictable for use in either target location or navigation equipment initial calibration.

APPENDIX A

TEST PLAN FOR TEST OF MEASURED VERSUS MAP-READ MAGNETIC DECLINATION

I. OBJECTIVE. The objective of this test is to determine the limitations on utilizing the map-posted declination as the input for a magnetic north reference unit.

II. METHOD. The method involves measuring declination:

1. At locations in various undeveloped areas unidentifiable on the 1:25,000 scale Quantico, Va., map No. V834S QUANTIFR.

2. Along the four cardinal radial lines emanating from the POS-406 (Platform Orientation System) test points established during the tests of February 1977.

III. TEST DETAILS. The test details include determining (1) the areas to be tested, (2) the equipment to be used, (3) the personnel required, (4) the number of work days, (5) the test schedule, (6) the test procedure, (7) sample data sheet, (8) data reduction technique, and (9) reconnaissance.

A. Test Areas. The test areas will be as follows:

1. Undeveloped areas found within the northern Virginia area.

2. Former POS-406 test points.

a. ETL.
b. South Leaf Road.
c. EPG.
d. Ft. Hunt.

B. Equipment. The equipment will consist of the SIAGL(surveying, instrument, azimuth, gyro, lightweight), and the M-2 aiming circle.

The logistics of the test require

1. One freshly charged 24-volt nickel-cadmium battery of 14-amp-hr capacity, each day of the test.

2. A government 4-wheel-drive vehicle each day of the test.

C. Personnel. A minimum of two people, trained to

1. Unpack SIAGL.

2. Set-up and read SIAGL.

(3). Shut -down and pack SIAGL.

(4). Set-up and read the M-2 aiming circle.

D. Length of Test. The length of test depends on the number of declinations required in the undeveloped areas and at the POS-406 test points as follows:

1. Undeveloped Areas. Pick out 25 points evenly distributed on the 1:25,000-scale Quantico Map. At each of these points, obtain the declination at two M-2 locations: one 10 meters east of the SIAGL and the second 10 meters north of the SIAGL. The second location will add 15 minutes to the time required to obtain the first, or approximately a total of 72 minutes for the two. The 25 undeveloped areas will then take 6½ days, assuming four declinations per day.

2. POS-406 Test Points. Obtain up to four declinations 10 meters apart along each of the four cardinal directions, giving a total of 16 declinations at each of the test points. Since the first M-2 declination can be obtained within an hour and the remaining 15 declinations can be obtained within four hours additional, the time required for each POS-406 test points will be 5 hours, excluding travel time. All of the 64 declinations for the four POS-406 test points can be completed in 4 days.

3. Reconnaissance. The undeveloped area points should be located in 3 days.

E. The Work Schedule. See figure A1 for work schedule.

F. Test Procedure. The procedure will consist of setting up the SIAGL and the M-2 aiming circle approximately 10 meters apart. A true north-referenced azimuth will then be transferred to the aiming circle by optically sighting between the two instruments. Transfer both the direct and reverse readings from the SIAGL. Record these azimuths. Put a stake with orange ribbon at each M-2 point.

Move the M-2 azimuth dial 10 mils off of the referenced azimuth momentarily, and return the dial to this azimuth; read and record the compass reading and the time. Repeat this 10 times.

The sequential steps involved in operating the SIAGL and the M-2 are included in the operational sequence section of this test plan.

G. Sample Data Sheet. See sample data sheet section.

H. Data Reduction Technique. The objective of the data reduction is to show the difference between the map-read declination and the compass-read declination.

If large differences between the map-read and the compass-read declination exist, the measured area should be carefully remeasured.

The compass-read declination will be averaged along with the magnetogram obtained variable declination; the difference of the two columns will then be equal to the average baseline constant declination for a given location.

I. Reconnaissance. Locate up to 25 points in the undeveloped areas evenly distributed on the referenced Quantico map and 500 meters away from man-made structures (see Immunity Distance Section). The points shall be marked with (wood) stakes and orange ribbon. These points shall be described in terms of distances measured from at least two land marks. Finally, these points shall be marked approximately on a topographic map.

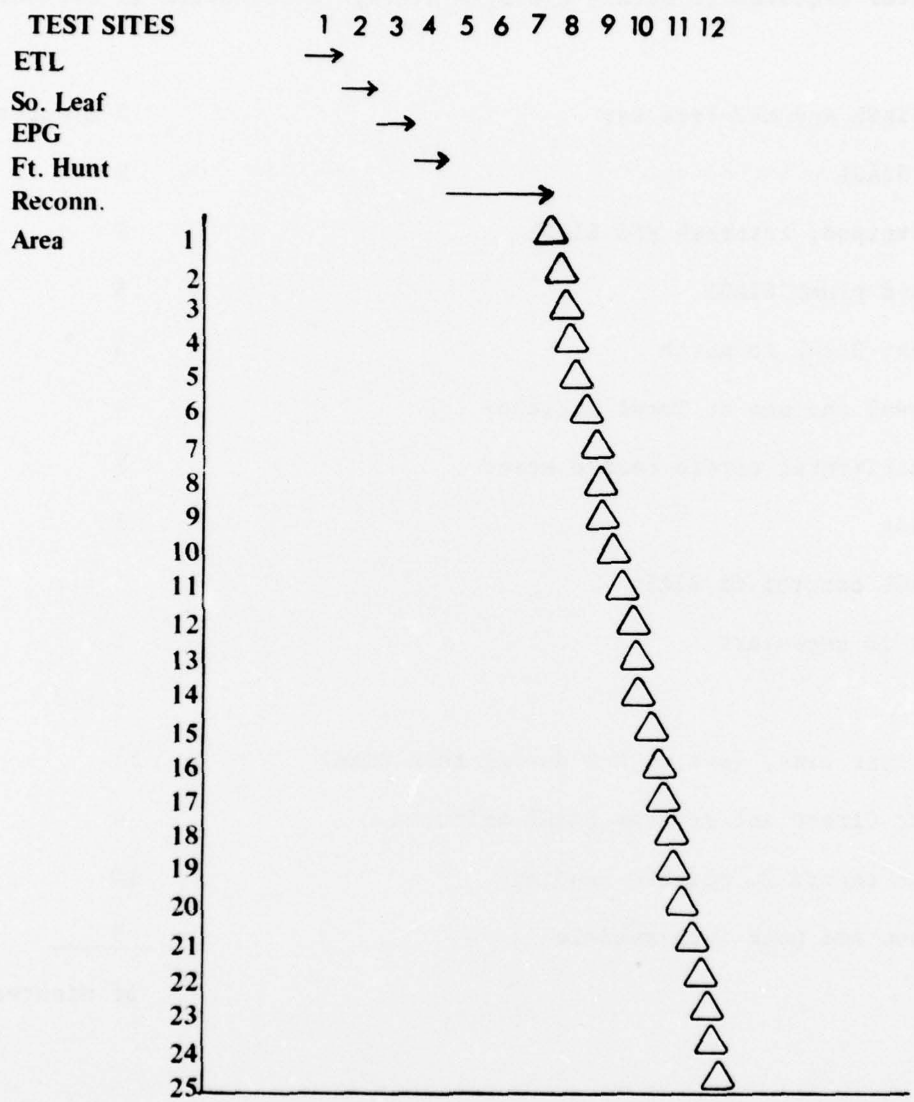


Figure A1. SCHEDULED WORK DAYS

DECLINATION TIME ALLOWANCES

The time required to obtain a single average declination is estimated as follows:

1.	Bring SIAGL and M-2 from car	2 minutes
2.	Unpack SIAGL	2
3.	Set up tripod, tribrach and SIAGL	2
4.	Level and plumb SIAGL	5
5.	Preorient SIAGL to north	3
6.	Fine level and set in local latitude	4
7.	Check horizontal circle record error	2
8.	Self test	1
9.	Set SIAGL control to BIAS	1 1/2
	Relevel if necessary	1
10.	Repeat 9	1 1/2
11.	Gyro - Sync time, (set up M-2 during this time)	12
12.	Transfer direct and reverse SIAGL azimuths	4
13.	Read and record 20 compass readings	10
14.	Shut down and pack into vehicle	5
		56 minutes

OPERATIONAL SEQUENCE OF MEASURING EQUIPMENT

I. SIAGL

1. Set up and connect cables.
2. Determine the center of the test point and center the SIAGL tripod over this point and level.
3. Preorient SIAGL reference mark to within 45° of true north.
4. Fine level SIAGL and set in the local latitude.
5. Set selector switch to THEO ILLUM position.
6. Check horizontal circle alignment to reference mirror (record error).
7. Set selector switch to SELF TEST position and proceed with self test.
8. Set selector switch to BIAS position and uncage.
9. Set bias compensation and cage.
10. Set selector switch in GC position and wait until GYRO SYNC indicator lights.
11. Uncage.
12. When GYRO SYNC and READ AZIMUTH indicators are lit read a distant azimuth directly on the integral theodolite horizontal circle and micrometer dials as shown in the Operator and Organizational Maintenance Manual, TM5-6675-250-12 paragraph 2-7, pages 2-15 through 2-17.
13. To secure SIAGL operation:

    a. Cage and set selector switch to BRAKE ON position.

    b. Set selector switch to PWR OFF position approximately 2 minutes after BRAKE ON.

    c. Reset gyro housing to reference position using the test selection switch set to "SERVO".

II. M-2 Aiming Circle

1. **Set up and level the aiming circle.**

2. **Set the known azimuth as determined by the SIAGL to the azimuth mark on the scales of the aiming circle.**

3. Sight the aiming circle on the SIAGL with the lower motion.

4. Release the magnetic needle.

5. Center the needle with the upper motion.

6. Read the declination from the scales (to 0.5 mil).

IMMUNITY DISTANCE FROM
MAGNETIC INFLUENCES

Power lines....................................	150 meters
Railroad tracks..............................	75
Tracked vehicles............................	75
Trucks, cars.................................	50
Fences..	30
Helmets, personal equipment, Weapons	10

SAMPLE

A sample sheet is shown in the accompanying figure. The variable magnetogram data will be obtained from Fredericksburg after the fact.

DECLINATION

Location: 10 meters E. ETL backyard Date: 19 May 1977
Dir. AZ. AV. AZ.
Rev. AZ.

TIME	COMPASS MEASURED DECLINATION	MAGNETOGRAM VARIABLE DECLINATION	BASELINE CONSTANT DECLINATION
0815	120		
0816	121		
0817	121		
0818	122		
0818.5	121		
0819	120		
0819.5	119		
0820	118		
0820.5	116		
0821	116		
0822	118		
0823	119		
0824	120		
0825	114		
0826	115		
0827	114		
0828	114		
0829	115		
0830	116		
0831	116		
TOTAL			
AVERAGE			

*AZ mark same as for the original ETL backyard azimuth.

APPENDIX B
QUANTICO, VA TEST SITE LOCATIONS
(In UTM Coordinates)

SITE NO.	NORTHINGS (METERS)	EASTING (METERS)
1	4,277,288	300,813
2	4,277,537	293,775
3	4,277,788	290,025
4	4,279,175	282,900
5	4,279,325	279,050
6	4,273,450	278,100
7	4,274,350	284,813
8	4,275,175	288,513
9	4,274,400	296,225
10	4,274,975	301,888
11	4,270,275	301,450
12	4,270,813	295,375
13	4,270,275	288,675
14	4,270,425	284,563
15	4,271,075	279,038
16	4,265,750	279,700
17	4,266,950	282,938
18	4,266,125	288,600
19	4,265,588	295,788
20	4,266,038	300,550
21	4,261,713	303,125

(APPENDIX B CONT)

SITE NO	NORTHINGS (METERS)	EASTING (METERS)
22	4,262,700	295,125
23	4,262,600	291,013
24	4,262,425	283,725
25	4,263,100	279,738

APPENDIX C
POS-406 TEST SITE LOCATIONS

Area Circle or Ref Point	*Test Circle Baseline Declination (Mils)	Aprox Easting (Meters)	Aprox Northing (Meters)	**Reference Azimuth (Mils) Grid N.	
1. EPG	133.8	309,758	4,291,752	5,503.4	Bldg Roof Left Corner
2. South Leaf	119.3	313,510	4,291,490	4,324.12	Bldg Roof Right Corner
3. ETL	113.2	313,565	4,290,890	6,239.4	Parking Lot Lamp Post
4. Ft. Hunt Park	139.3	321,400	4,286,920	4,792.5	Top of Fire Hydrant

* Baseline declination is derived from the measured value of declination.

** Azimuths were measured using the Wild, Ark-1, gyroscopic north-seeker surveying instrument, and the surveying instrument; azimuth, gyro, lightweight (SIAGL).